

MINERvA CCQE Analysis: First Results

Dr. Joseph Walding
College of William and Mary



DNP 2011 Fall Meeting

On behalf of the MINERvA
Collaboration

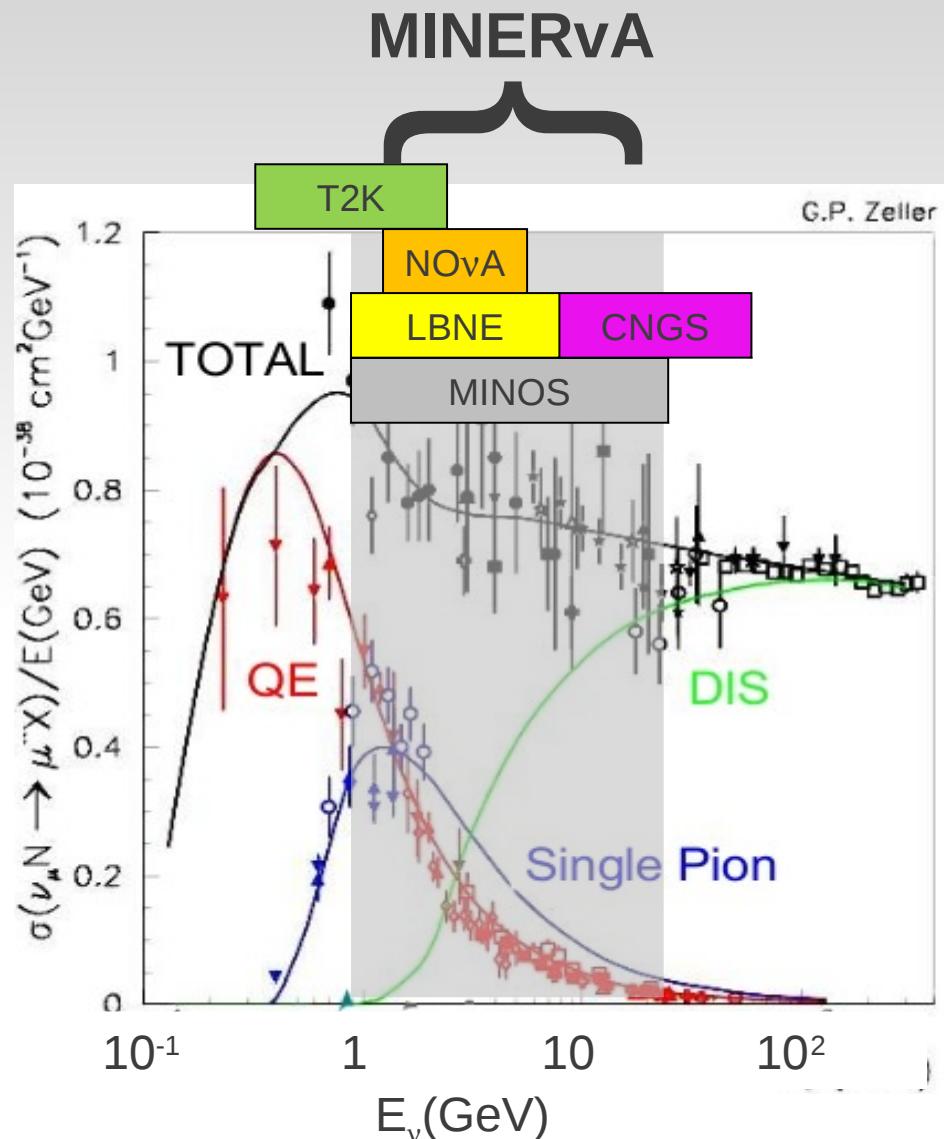
Outline

- Motivation
- NuMI Beamline
- MINERvA Detector
- CCQE Analysis
- Distributions
- Summary



MINERvA: Motivation

- Multiple oscillation experiments in O(GeV) neutrino beams
- Multiple significant cross-sections
 - CCQE
 - Resonant Pion Production
 - DIS
- Precision oscillation measurements require precision cross-section measurements
- Understand oscillation backgrounds
 - $\nu_\mu \rightarrow \nu_e$: π^0 production



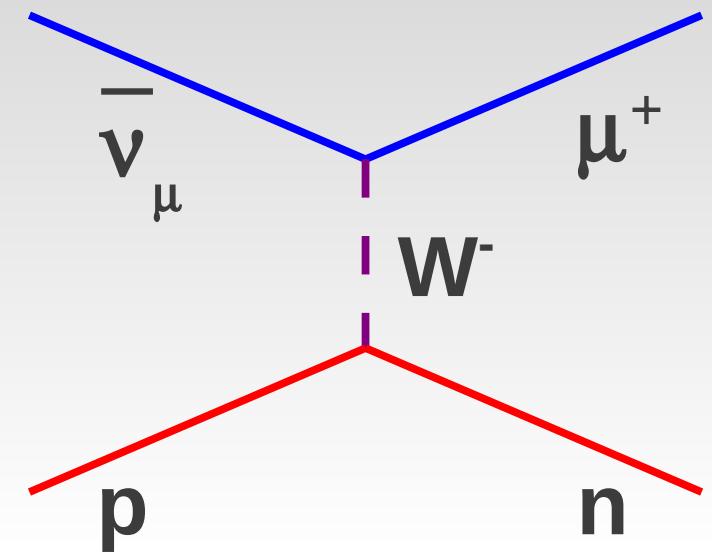
note: plot does not include MiniBooNE or SciBooNE data



MINERvA: CCQE

- Charged Current Quasi-Elastic (CCQE) scattering
- Neutron not always observed
- Vertex separation between neutron and muon
- Reconstruct neutrino energy using only muon kinematics

$$E_{\bar{\nu}_\mu} = \frac{2(m_p - \epsilon_B)E_\mu - ((m_p - \epsilon_B)^2 + m_\mu^2 - m_n^2)}{2((m_p - \epsilon_B)^2 - E_\mu + \sqrt{E_\mu^2 - m_\mu^2} \cos \theta_\mu)}$$
$$Q^2 = 2E_{\bar{\nu}_\mu}(E_\mu - p_\mu \cos \theta_\mu) - m_\mu^2$$



$$\bar{\nu}_\mu + p \rightarrow \mu^+ + n$$

Binding energy
 $\epsilon_B = 30 \text{ MeV}$



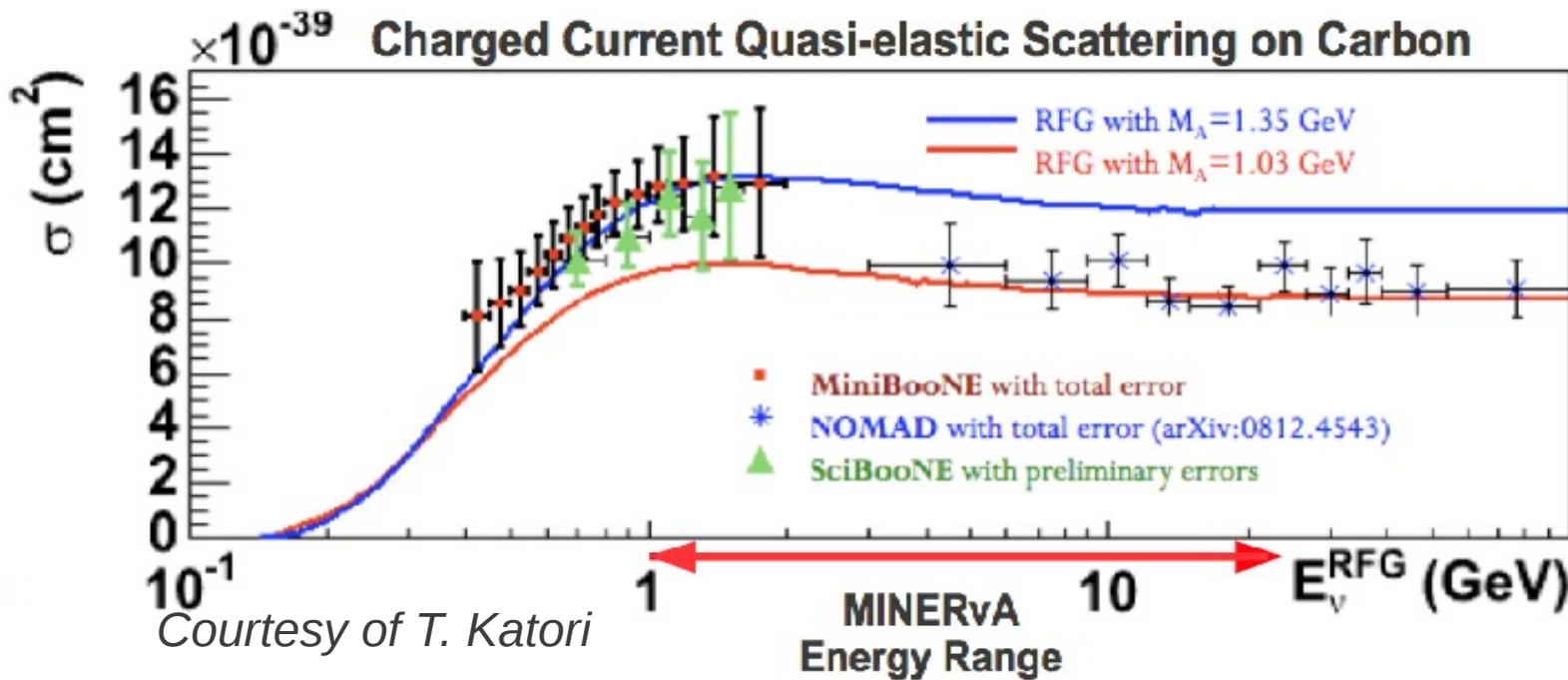
MINERvA: CCQE

- CCQE cross-section calculated using axial and vector form factors
 - Vector form factors have been measured using electron-nucleon scattering
 - Axial form factor (F_A) can be measured using neutrino-nucleon scattering
 - Dipole approximation \longrightarrow
 - Could take another form

$$F_A(Q^2) = \frac{F_A(0)}{\left(1 + \frac{Q^2}{M_A^2}\right)^2}$$

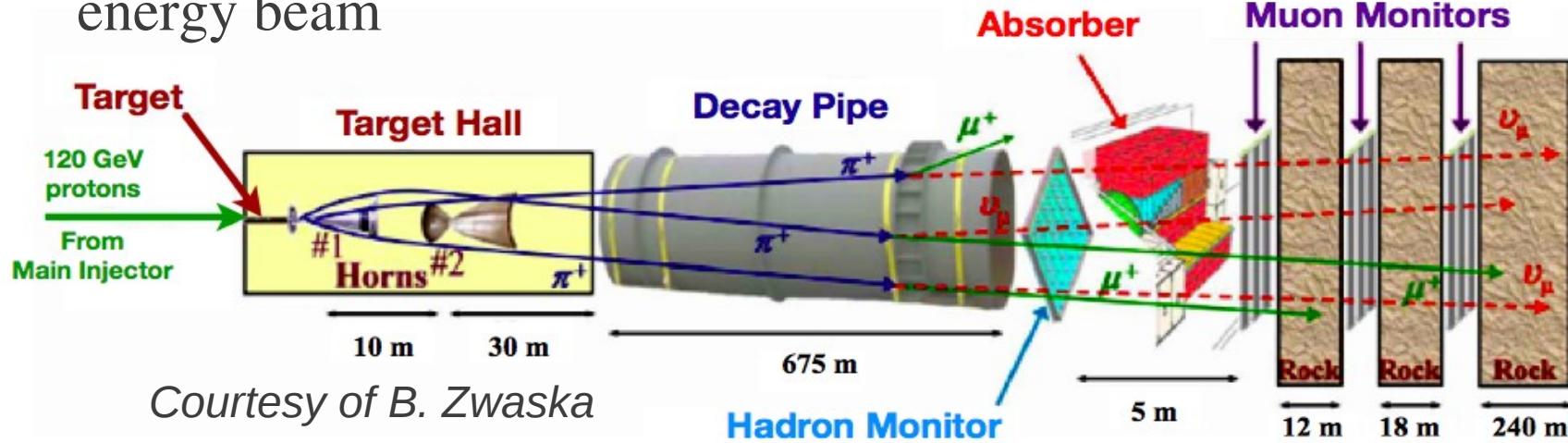
MINERvA: CCQE Motivation

- CCQE: Common oscillation signal (T2K, MiniBooNE), flux standard candle
- Discrepancy between low and high energy CCQE cross-section measurements
 - We measure - interaction, nuclear effects, detector response
- MINERvA has capability of answering this question
 - Broad energy spectrum, multiple targets over range of A
 - Sensitive enough detector to look at different detector signatures

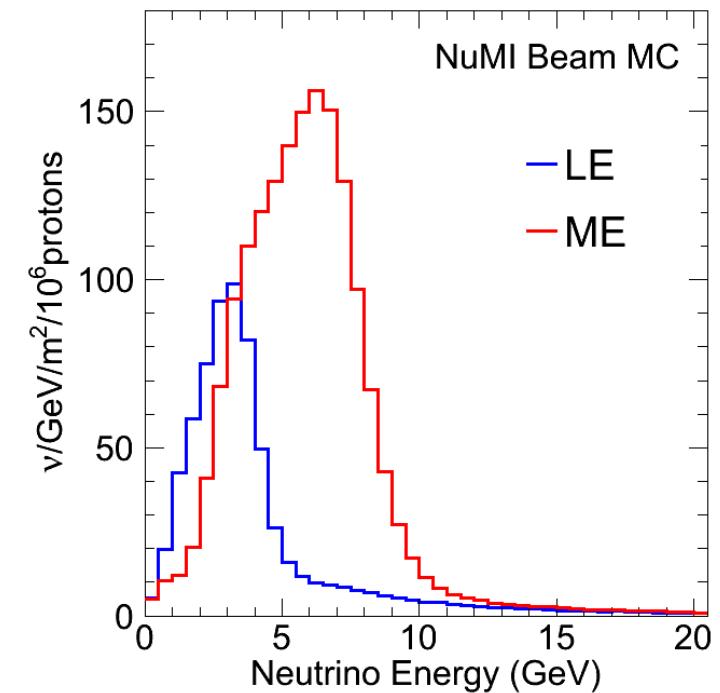


MINERvA: NuMI Beamlne

- 120 GeV protons collide with carbon target
 - Resultant mesons (π/K) focused
 - Decay to neutrinos
- Reversible horn polarity - sign select mesons:
 - ν_μ and $\bar{\nu}_\mu$ beam capability
- MINERvA will run in low and medium energy beam

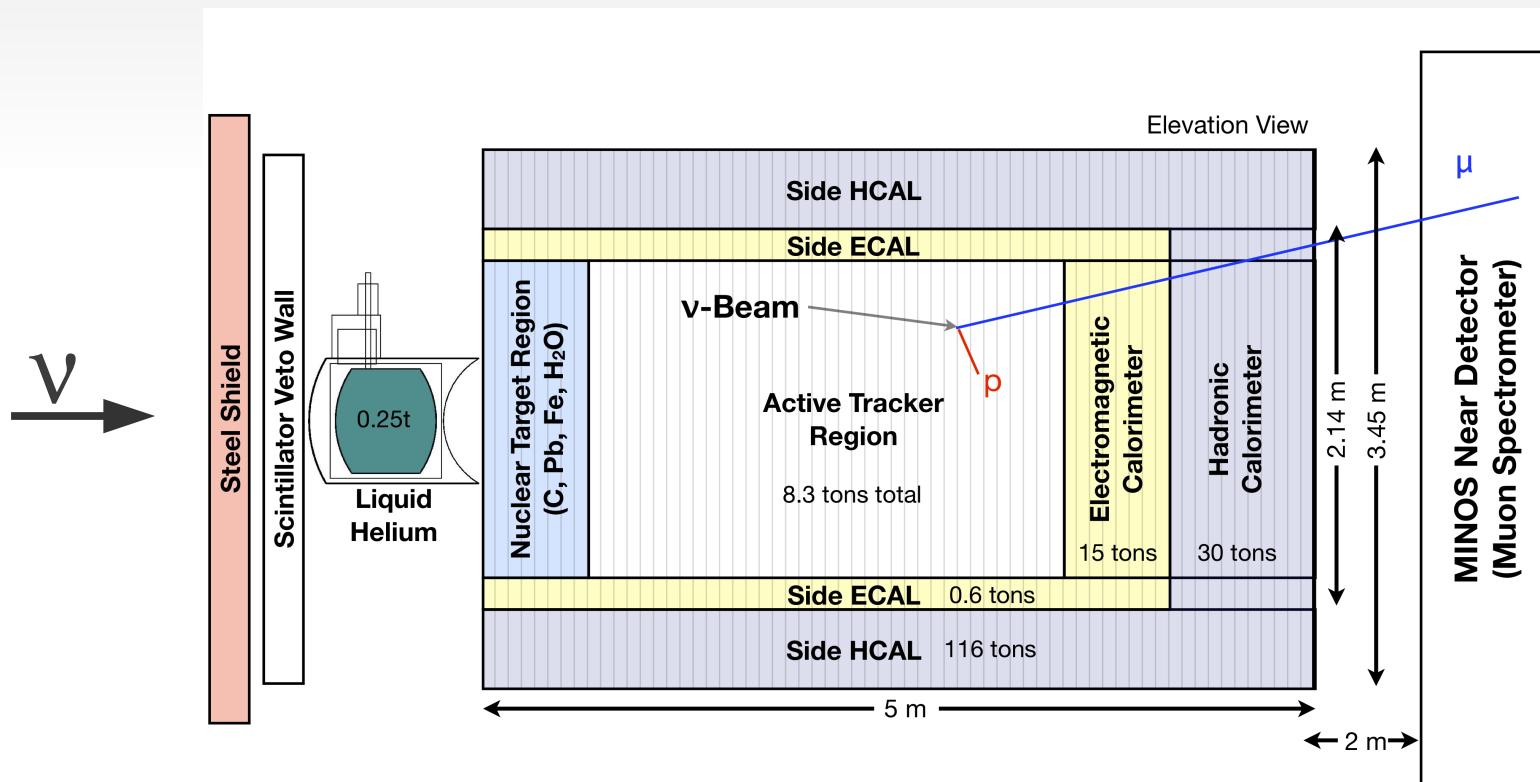


ν spectrum: $\bar{\nu}$ similar

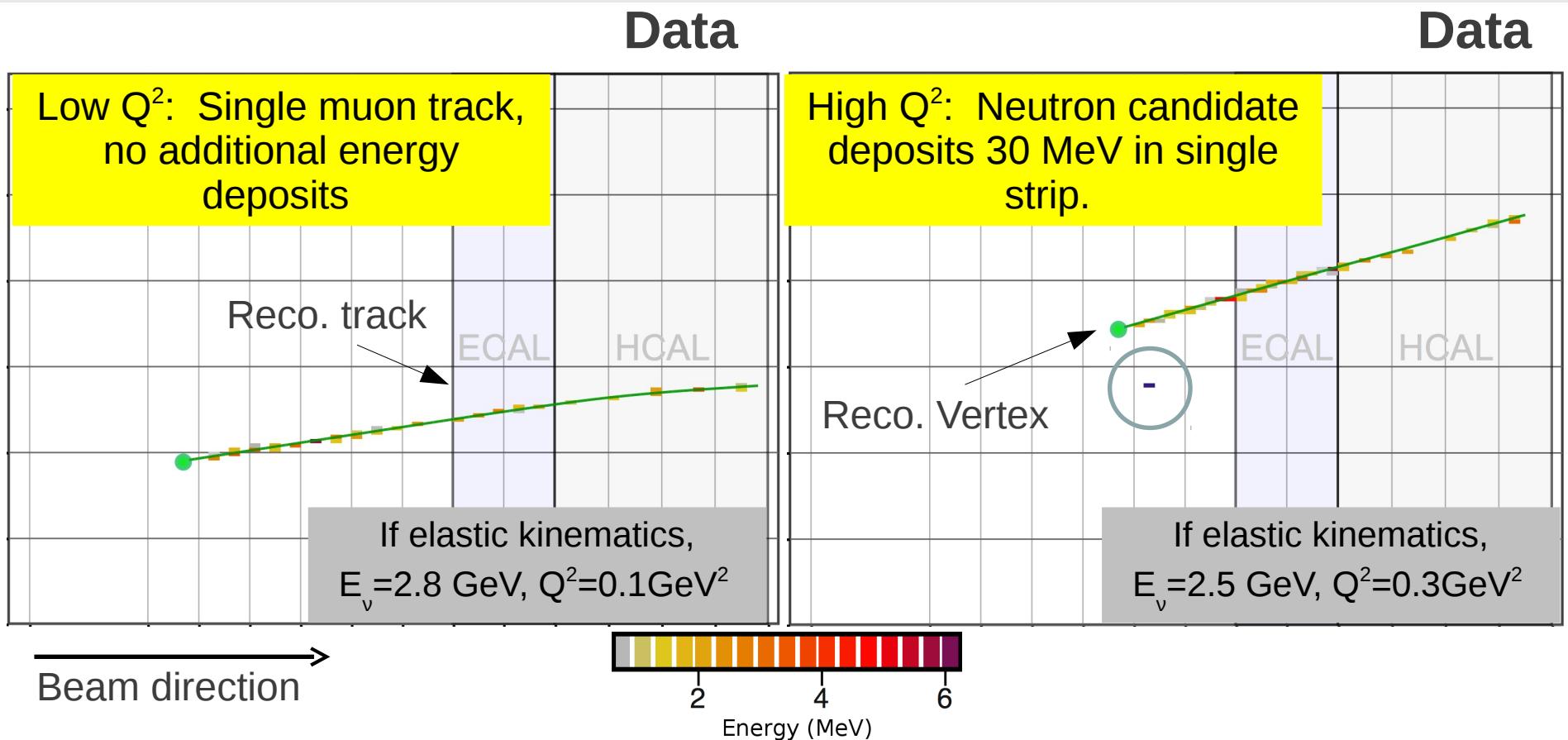


MINERvA: The Detector

- MINERvA: 120 planes, 200 tons, 32K channels
 - Multiple nuclear targets: He, C, CH, H₂O, Fe, Pb
- MINOS used as muon spectrometer
 - Magnetised – can determine muon charge

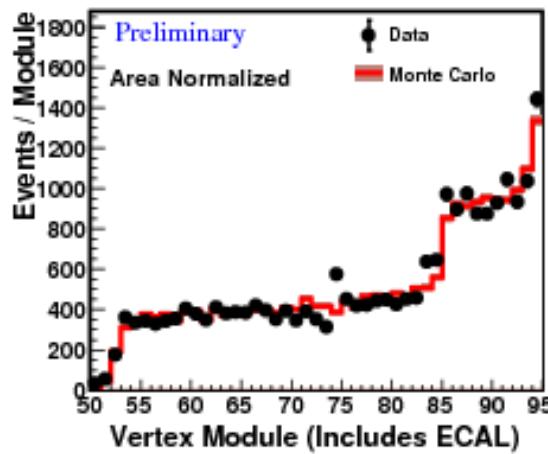
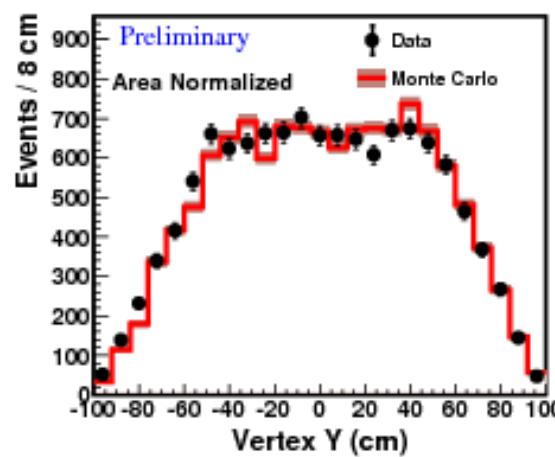
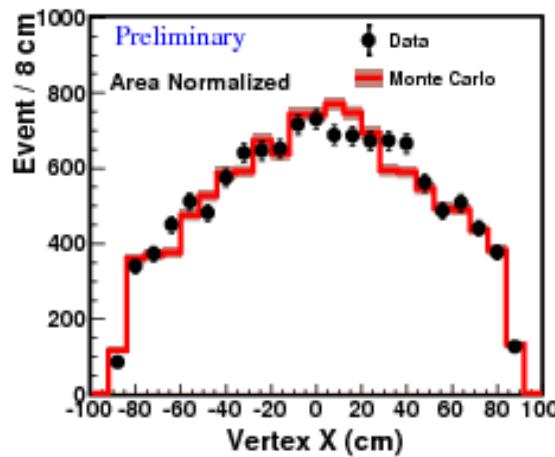


MINERvA: $\bar{\nu}_\mu$ CCQE Signature



MINERvA: CCQE Analysis

Vertex Distributions for CC events

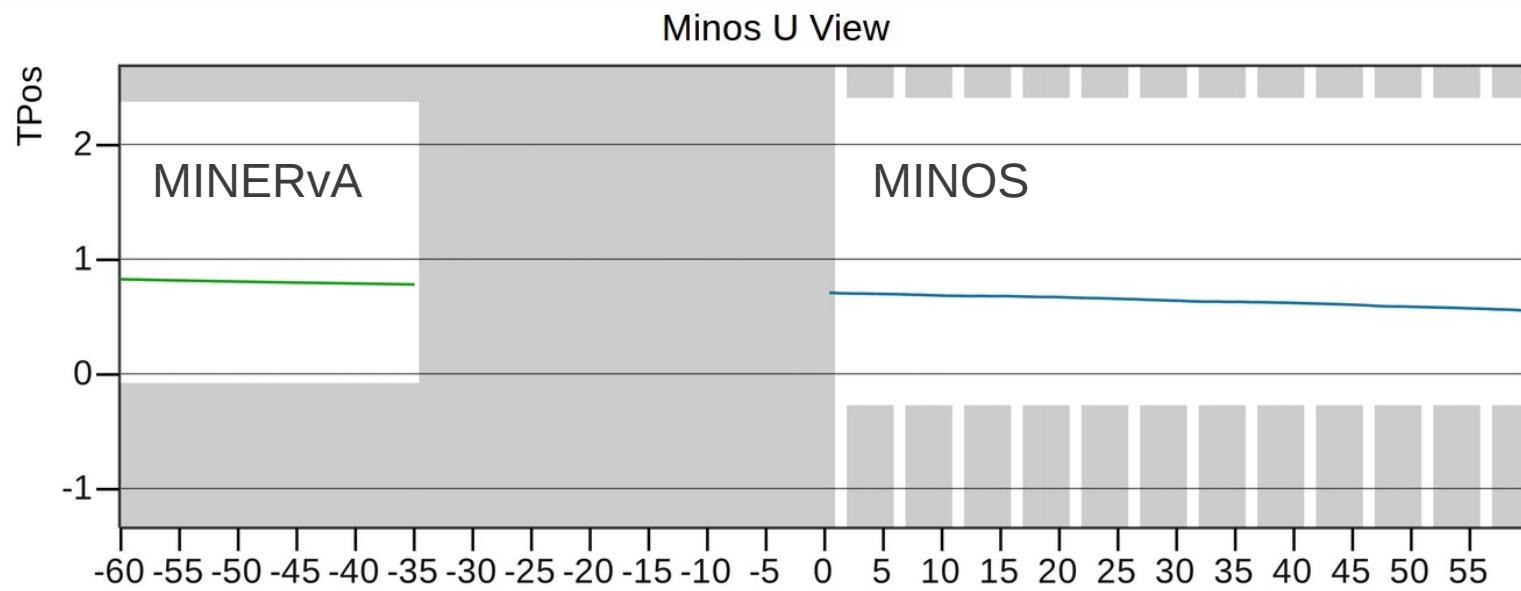
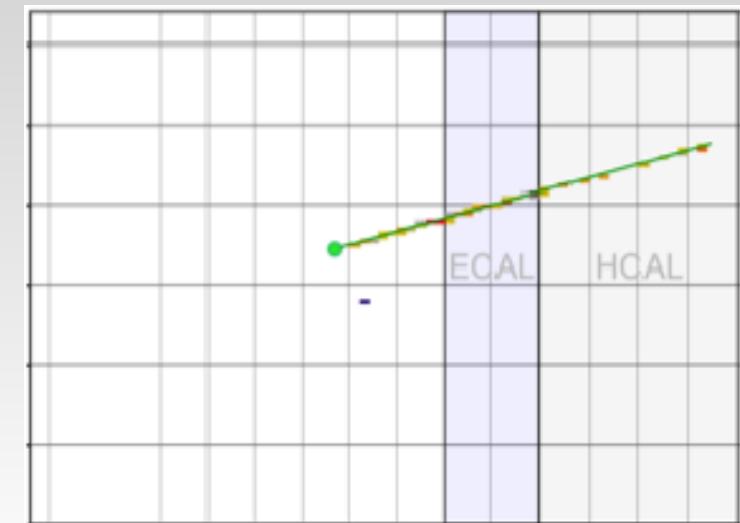


- Anti-neutrino analysis on partial detector era
 - 64 planes (~ half MINERvA detector)
 - 4×10^{19} protons on target (POT)
 - Current data set = 1.7×10^{20} POT
 - Monte Carlo: $M_A = 0.99 \text{ GeV}/c^2$
- Good data-to-MC agreement seen in vertex distributions



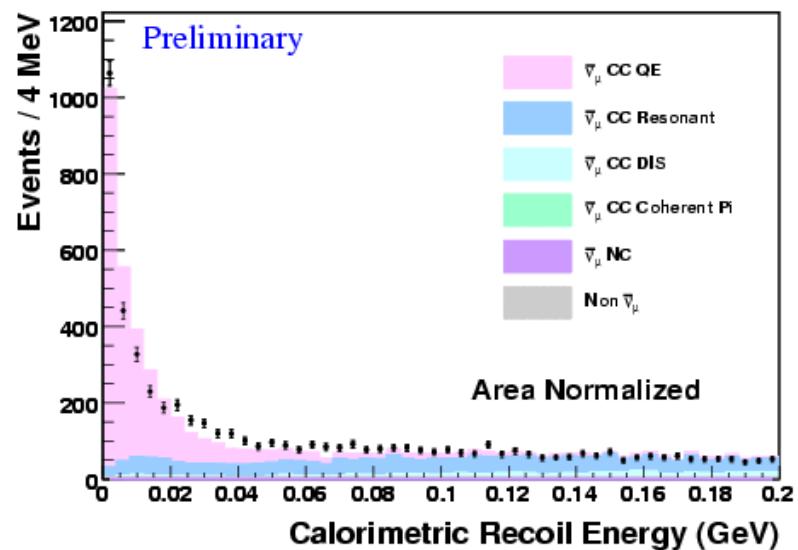
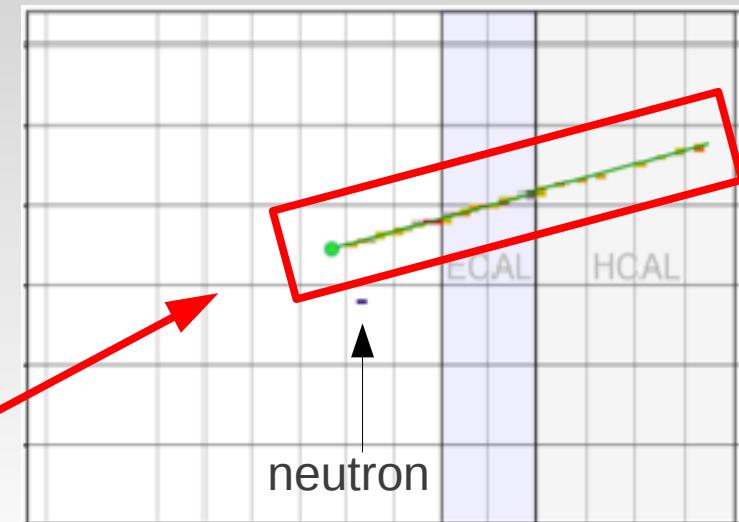
MINERvA: CCQE Analysis

- Event Selection
 - Event vertex in MINERvA fiducial volume (2.86 tons)
 - CH target
- Muon track enters MINOS detector
 - Muon charge selection



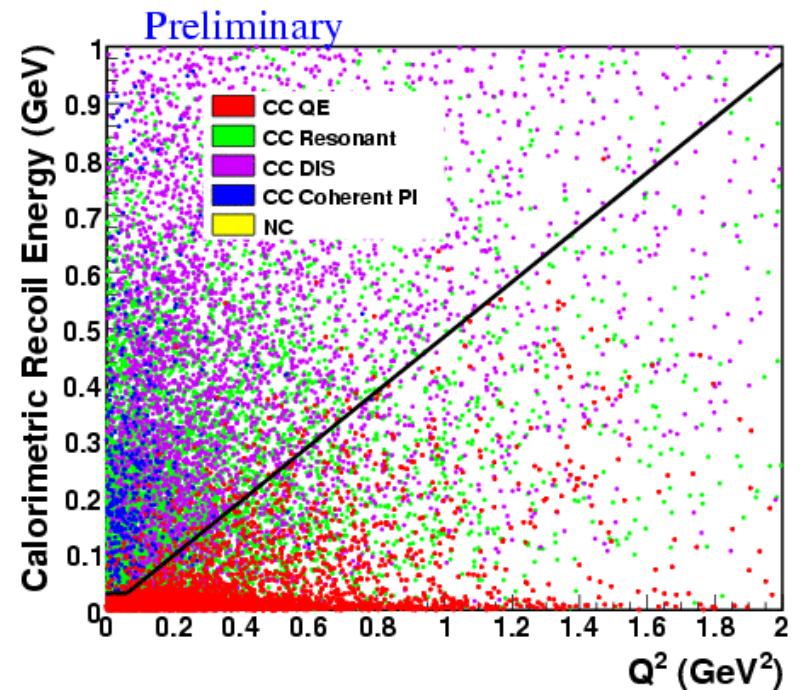
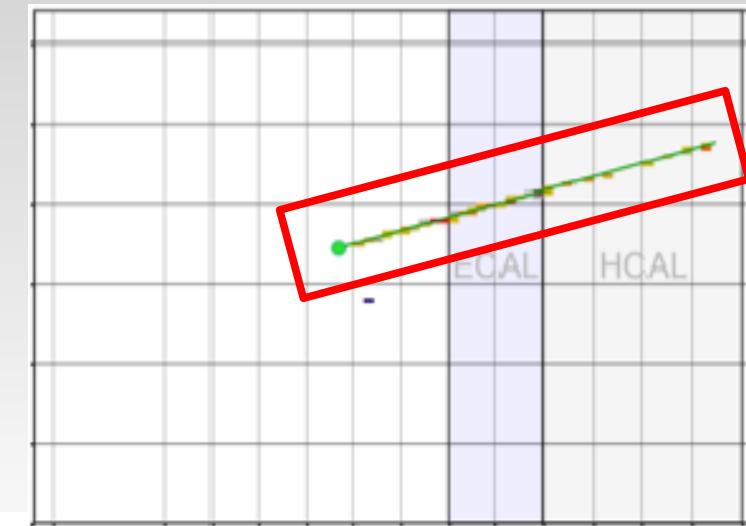
MINERvA: CCQE Analysis

- Event Selection
 - Event vertex in MINERvA fiducial volume (2.86 tons)
 - CH target
- Muon track enters MINOS detector
 - Muon charge selection
- Recoil energy cut
 - Sum all energy outside 5cm of track
 - QE sample at low recoil energy
- However high Q^2 CCQE events rejected
 - Introduce Q^2 dependent recoil cut
 - Scales with $Q^2/2m_p$



MINERvA: CCQE Analysis

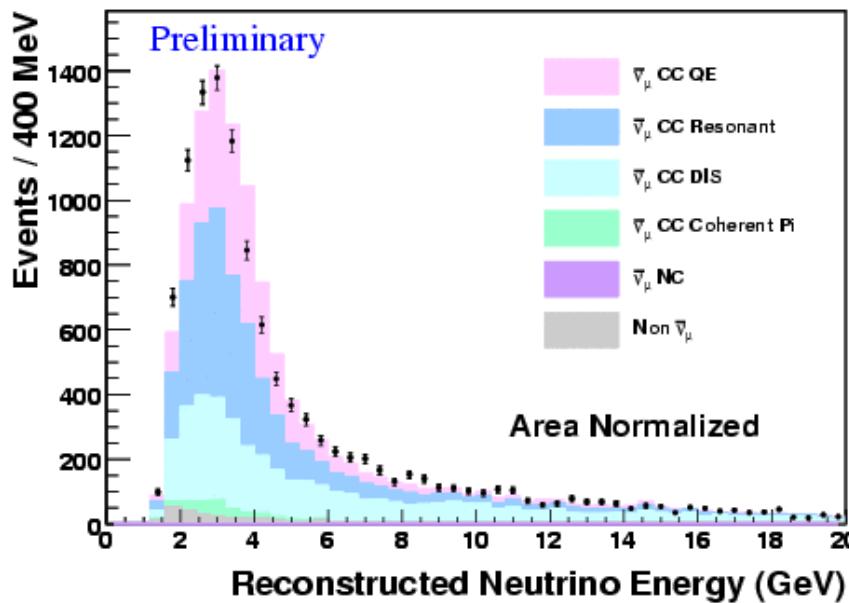
- Event Selection
 - Event vertex in MINERvA fiducial volume (2.86 tons)
 - CH target
- Muon track enters MINOS detector
 - Muon charge selection
- Recoil energy cut
 - Sum all energy outside 5cm of track
 - QE sample at low recoil energy
- However high Q^2 CCQE events rejected
 - Introduce Q^2 dependent recoil cut
 - Scales with $Q^2/2m_p$



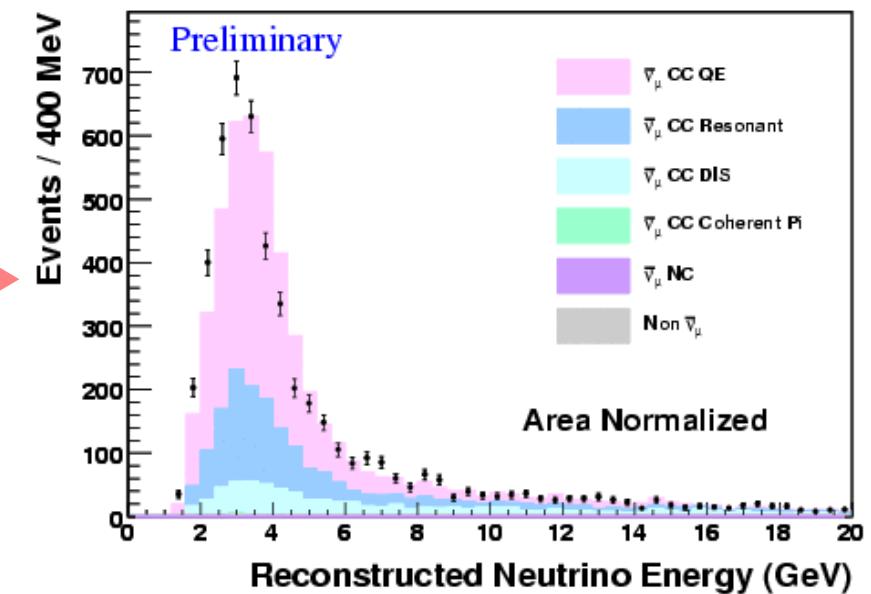
MINERvA: Distributions

- Area normalised plots, statistical errors only
- Recoil cut effectively selects CCQE events
- Fairly good shape agreement

Before Recoil Cut

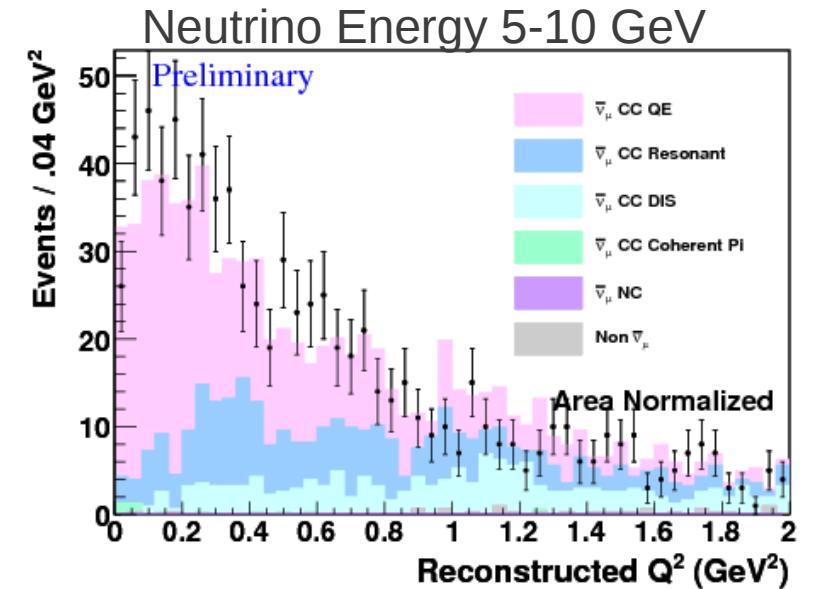
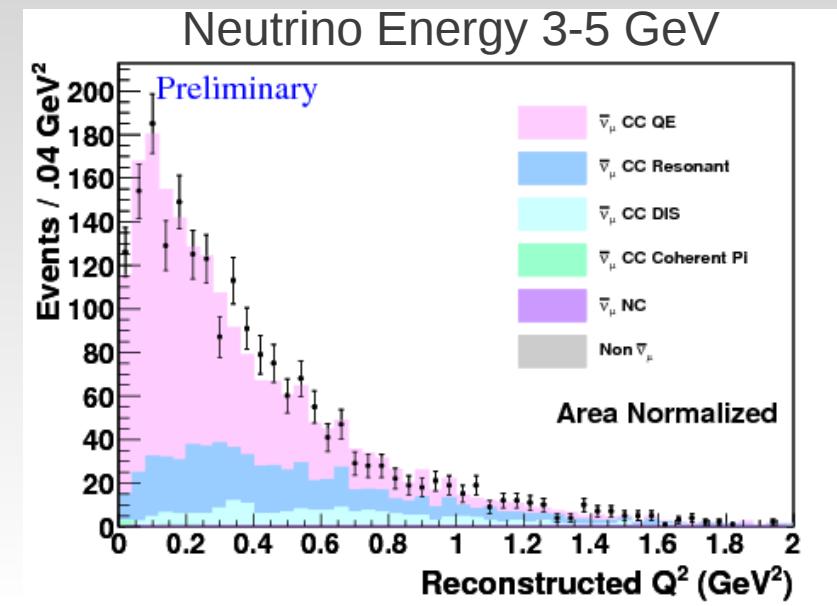
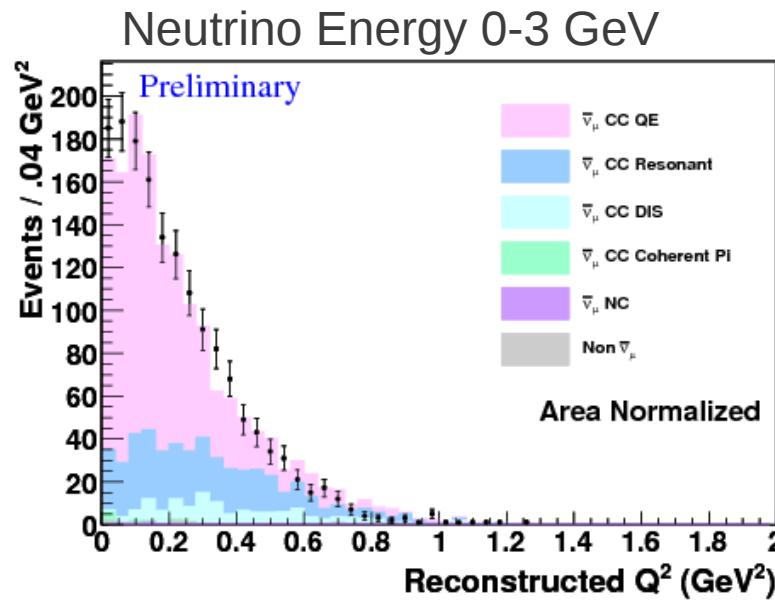


After Recoil Cut



MINERvA: Distributions

- Area normalised. Statistical errors only
- Broad Q^2 distribution, large background at high Q^2
- Good shape agreement for all energy ranges



Summary

- MINERvA has unique ability to answer numerous puzzles seen in current cross-section data
- Have shown that MINERvA can effectively select CCQE events
- Work ongoing on an increased data set with the goal of producing CCQE cross-section results soon...

Stay tuned!



With thanks to: Fermilab DOE, NSF, MINOS Collaboration

MINERvA Collaboration:

G. Tzanakos
University of Athens

J. Cravens, M. Jenkins, S. Kopp, L. Loiacono, J. Ratchford, R. Stevens IV
University of Texas at Austin

D.A.M. Caicedo, C.M. Castromonte, H. da Motta, G. A. Fiorentini, J.L. Palomino
Centro Brasileiro de Pesquisas Fisicas

J. Grange, J. Mousseau, B. Osmanov, H. Ray
University of Florida

D. Boehlein, R. DeMaaat, N. Grossman, D. A. Harris, J. G. Morfin, J. Osta,
R. B. Pahlka, P. Rubinov, D. W. Schmitz, F.D. Snider, R. Stefanski
Fermilab

J. Felix, A. Higuera, Z. Urrutia, G. Zavala
Universidad de Guanajuato

M.E. Christy, C. Keppel, P. Monaghan, T. Walton, L. Y. Zhu
Hampton University

A. Butkevich, S.A. Kulagin
Inst. Nucl. Reas. Moscow

G. Niculescu, I. Niculescu
James Madison University

E. Maher
Mass. Col. Lib. Arts

L. Fields, B. Gobbi, L. Patrick, H. Schellman
Northwestern University

N. Tagg
Otterbein College

S. Boyd, I. Danko, S.A. Dytman, B. Eberly, Z. Isvan, D. Naples, V. Paolone
University of Pittsburgh

A. M. Gago, N. Ochoa, J.P. Velasquez
Pontificia Universidad Catolica del Peru

S. Avvakumov, A. Bodek, R. Bradford, H. Budd, J. Chvojka, M. Day, H. Lee, S. Manly,
C. Marshall, K.S. McFarland, A. M. McGowan, A. Misilvec, J. Park, G. Perdue, J. Wolcott
University of Rochester

G. J. Kumbartzki, T. Le, R. D. Ransome, E. C. Schulte, B. G. Tice
Rutgers University

H. Gallagher, T. Kafka, W.A. Mann, W. P. Oliver
Tufts University

C. Simon, B. Ziemer
University of California at Irvine

R. Gran, M. Lanari
University of Minnesota at Duluth

M. Alania, A. Chamorro, K. Hurtado, C. J. Solano Salinas
Universidad Nacional de Ingeniera

W. K. Brooks, E. Carquin, G. Maggi, C. Pea, I.K. Potashnikova, F. Prokoshin
Universidad Tecnica Federico Santa Mara

L. Aliaga, J. Devan, M. Kordosky, J.K. Nelson, J. Walding, D. Zhang
College of William and Mary

Back-up



Dr. Joseph Walding

DNP 2011 Fall Meeting

18



MINERvA: Data Taking

